DOE/YMPO-001

Final Recommendations of the Peer Review Panel On the Use of Seismic Methods For Characterizing Yucca Mountain and Vicinity

Submitted to

The United States Department of Energy
Yucca Mountain Site Characterization Project

January 22, 1991

by:

The Seismic Methods Peer Review Panel

Daniel R. Burns, Chairman
Stephen Danbom
Clint W. Frasier
George Thompson
Roger Turpening

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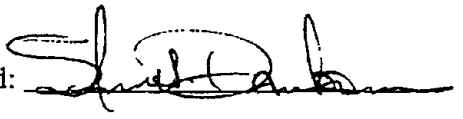
As a member of the Peer Review Panel for Seismic Methods I hereby acknowledge that I concur with the contents of this final recommendations report dated November 30, 1990.

signed: _____ date: January 22, 1991

Daniel R. Burns, Chairman

As a member of the Peer Review Panel for Seismic Methods I hereby acknowledge that I concur with the contents of this final recommendations report dated January 22, 1990.

signed:  date: 1/23/91

Stephen Danbom

As a member of the Peer Review Panel for Seismic Methods I hereby acknowledge that I concur with the contents of this final recommendations report dated January 22, 1990.

signed: Clint W. Frasier date: Jan 22, 1991

Clint W. Frasier

As a member of the Peer Review Panel for Seismic Methods I hereby acknowledge that I concur with the contents of this final recommendations report dated January 22, 1990.

signed: George A. Thompson date: 1-23-91

George A. Thompson

As a member of the Peer Review Panel for Seismic Methods I hereby acknowledge that I concur with the contents of this final recommendations report dated January 22, 1990.

signed: Roger Turpening date: Jan 22, 1991

Roger Turpening

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EXECUTIVE SUMMARY

The Seismic Peer Review took place at the DOE Yucca Mountain Project Office in Las Vegas during the period of September 10-13, 1990. The Panel was formed to address the role of seismic methods in characterizing the structural setting at Yucca Mountain, the proposed site of the nation's first commercial high level radioactive waste repository. The Panel was charged with deciding whether seismic methods, which had been utilized at Yucca Mountain with mixed results in the past, could provide useful information about the Tertiary structure in the Yucca Mountain area. The objectives of using seismic methods at Yucca Mountain are to: a) obtain information about the structural character of the Paleozoic-Tertiary (Pz-T) contact, and b) obtain information about the structural and volcanic details within the Tertiary and Quaternary section.

As a result of the Peer Review process the Panel has the following general recommendations: a) coordination and integration of all seismic methods is critical to the success of the geophysical program, and b) the success of the program can be best met by placing the responsibility with an identified individual. Integration with other geophysical and geological databases is also essential for obtaining the most accurate interpretation

The Panel's specific recommendations are prefaced by several key comments: 1) the panel believes that the seismic reflection method can provide high resolution information concerning the structural setting at Yucca Mountain, specifically in the depth ranges of the Paleozoic-Tertiary contact; 2) the panel believes that it is critical that the reflection data be tied to the subsurface geology at a well point which penetrates the Cenozoic section in an area of expected good quality seismic data; 3) the panel believes that shear wave information may provide an additional avenue for obtaining useful structural information at Yucca Mountain, and as such suggests that a shear wave source test be carried out prior to acquiring the seismic profile.

The Panel recommends that a four part program be undertaken to test the utility of seismic reflection data for characterizing the structural setting of the Yucca Mountain area. The Panel feels strongly that all four parts of the program must be completed in order to provide the highest probability of success. The four parts of the program are:

a) drill or extend a deep hole in Crater Flat to provide depth control and allow for the identification of seismic reflectors in an area where good quality seismic reflection data is expected. We suggest that the deepening of the existing VH1 well in Crater Flat be considered because of its location and to reduce costs.

b) undertake a full seismic noise test in Crater Flat, test 2D receiver arrays as well as linear arrays; perform an expanding spread test using both P and S wave sources to obtain a quick look at the reflection quality in the area and see if shear wave reflections might provide structural information in areas of unsaturated rock.

c) acquire a P wave seismic reflection profile across Crater Flat through the deep control well, across Yucca Mountain, and continuing into Jackass Flats

d) Acquire a standard VSP in the deep control well to tie the seismic data into depth and to identify reflectors correctly.

Specific recommendations concerning the acquisition of seismic reflection data include the following:

a) Lower the vibrator sweep frequency at the low end to add an octave to the sweep band (relative to the Amargosa Desert reflection line AV-1)

b) add more sweeps per vibrator point to increase the total source energy (relative to the Amargosa Desert reflection line AV-1)

c) test the use of dynamite sources

d) the proposed line location must be straightened out to avoid smearing the common reflection points over an unacceptably large area under Yucca Mountain

e) undershoot Yucca Mountain by leaving receiver spreads on one side of the mountain and shooting sources on the other side (and vice-versa); decrease the shot point interval during this exercise to build up the fold under Yucca Mountain.

The Panel stresses the following points in regard to the acquisition of this VSP:

a) the VSP design and acquisition must be coordinated with the reflection work to ensure success

b) the deep control well must have a good, complete cement job behind casing in order to get adequate horizontal geophone coupling for offset VSP and shear wave VSP acquisition

c) the issue of tool coupling in dry boreholes must be adequately addressed when designing the experiment and selecting equipment (most VSP and checkshot data at Yucca Mountain is not useable above the water table because of this problem)

Although some disagreement exists within the committee concerning the applicability of refraction methods for providing information on the shallow Tertiary structure, there is a clear consensus that interpretation of refraction data at Yucca Mountain is very difficult for three reasons: 1) the shallow Tertiary section contains alternating high and low velocity zones, 2) the sub-Tertiary "basement" is composed of highly variable lithologies with highly variable velocities, and 3) the steep, narrow basins in the Yucca Mountain area present a difficult geometry for acquiring adequate data. In light of the fact that the previously acquired Yucca Mountain reconnaissance refraction survey was conducted using large station spacing and few shots, the panel suggests that if explosive sources are used for any portion of the proposed reflection profile across Crater Flat and Yucca Mountain, consideration be given to recording wide angle/refraction data simultaneously. Such data would provide additional velocity information as well as potentially useful refraction information about the deeper section at Yucca Mountain. The use of close station spacing, numerous shots, and appropriate analysis techniques may provide useful results.

INTRODUCTION

The Seismic Peer Review Panel was formed to address the role of seismic methods in characterizing the structural setting at Yucca Mountain, the proposed site of the nation's first commercial high level radioactive waste repository. The Panel was charged with deciding whether seismic methods, which had been utilized at Yucca Mountain with mixed results in the past, could provide useful information about the Tertiary structure in the Yucca Mountain area. The primary objectives of using seismic data, as defined in the next section, are to image the structure of the Paleozoic-Tertiary contact, as well as the structure within the Tertiary section itself. The presence of a thick unsaturated zone, the existence of high velocity welded tuff units, and the steep topography over portions of the site make this a very difficult area in which to acquire seismic reflection data. In spite of these difficulties, the Panel believes that the reflection method can achieve the needed resolution to address the key objectives of such a survey. There appears to be a large degree of uncertainty about the structural details at the Yucca Mountain site, much of which hinges on the Paleozoic-Tertiary contact, which may or may not be a detachment surface. This key question has important ramifications concerning the potential for future seismic activity along the normal faults which are present throughout the area. The Panel believes that this key question can be answered by the seismic reflection method, taking into consideration the recommendations presented in this report.

OBJECTIVES

Any geophysical activity must be objective driven. The need for specific objectives is critical in devising observational experiments in order to properly design the acquisition of data to answer key scientific questions. The acquisition of geophysical data in general, and seismic data in particular, must be focussed on a very specific set of objectives because of the non-uniqueness inherent in the interpretation of such data. Certain failure will result from collecting seismic data without a clear plan, or with an overly broad set of objectives designed to answer too many questions at once.

During the Peer Review Meeting, the Panel and the USGS participants spent one-third of the Agenda discussing the objectives of proposed seismic data acquisition plans. The importance of these objectives was also stressed in the Peer Review Plan (Appendix A) question list. In terms of seismic reflection data acquisition, one of the important constraints is to base the effort on a specific depth range of interest in order to optimize the results. The final objectives, which were agreed upon by the USGS participants, are the following:

1. To obtain information about the structural setting of the Paleozoic-Tertiary (Pz-T) contact. Specifically, to image the normal faults in the Tertiary section and answer the question of whether these faults cut the Pz-T contact and continue to seismogenic depths, or whether these faults are listric to this contact with the contact representing a detachment surface.

2. To obtain information about the internal structure of the Cenozoic section. Specifically, to image the strata, faults, and basalt flows in the Tertiary section in order to provide control on the character and dating of structural deformation in the Yucca Mountain area.

The Panel feels that these two objectives are well posed and can form the basis of a seismic data acquisition effort at Yucca Mountain.

There were two other objectives which were discussed but these were agreed by all parties to have a lower priority at this stage of activity. Those objectives included the imaging of the Paleozoic section structure and the identification of high amplitude "bright spots" in the deep crust which might indicate the presence of magma. In addition, important discoveries, such as reflective detachment faults within the Paleozoic section or basaltic intrusions within the Cenozoic section, may also be by-products from the reflection data.

PANELISTS AND EXPERTISE

The panel members were selected to provide expertise in the critical technical areas which were identified by the Chairman. These areas were: the acquisition, processing, and interpretation of seismic reflection data; borehole geophysics; the seismic refraction method, and basin and range tectonics. The original panel consisted of 6 members covering all of these areas (see the panel list in the Peer Review Plan in Appendix A). Due to unforeseen circumstances, one member (Dr. Terry Young) was forced to withdraw from participation 2 days before the peer review meeting (see letter in Appendix D). Although his participation was missed, the remaining 5 members of the panel covered all critical technical areas of the Peer Review. Panel members Dr. Clint Frasier and Dr. Steve Danbom are experts in all facets of seismic reflection exploration and as such were able to provide expertise in seismic data processing as well as acquisition and interpretation. The final Peer Review Panel Member list is given in Appendix E.

MEETING AND PRESENTATIONS

The Peer Review took place at the DOE Yucca Mountain Project Office in Las Vegas on September 11 - 13, 1990. Prior to the review, four of the panel members (Burns, Frasier, Thompson, and Turpening) took part in a field trip to Yucca Mountain and the surrounding area. This trip, led by Ken Fox of the USGS, provided a first hand look at the difficulties to be encountered by any geophysical field effort.

The Review meeting itself consisted of a day and a half of presentations by members of the USGS (and one presentation by a Scientist from the Lawrence Berkeley Lab). The final agenda of the meeting is given in Appendix C. The rationale for this agenda was to define the objectives of using seismic methods at Yucca Mountain (Tuesday afternoon session), review the velocity structure in and around Yucca Mountain in order to ascertain the existence of reflectors which could be imaged by seismic methods (Wednesday morning session), and to discuss the utility of seismic data acquired previously in the area and the possibilities of acquiring data of higher quality in future surveys (Wednesday afternoon). The panel met privately on Thursday to discuss the existing and proposed geophysical surveys and to formulate recommendations for the use of seismic methods for characterizing Yucca Mountain. These recommendations were presented and videotaped on Thursday afternoon at the Yucca Mountain Project Office.

The Peer Review Panel was very pleased with the presentations and efforts of the USGS personnel that took part in the review. The panel would like to single out three people for their efforts. Dr. Tom Brocher's work on the AV-1 line in the Amargosa Desert and his presentation of those results was outstanding. The panel was impressed by his attention to detail as well as his openness to suggestions and questions by the panel members. Dr. Ken Fox provided a wealth of geologic understanding and openness to competing hypotheses concerning the geology and tectonic history of the Yucca Mountain area. Finally, Dr. Phil Nelson presented results of the borehole logging effort at Yucca Mountain. The approach taken and the insight gained from that effort were well received.

PANEL RECOMMENDATIONS

The Peer Review Panel has formulated a specific plan for the use of seismic methods for characterizing Yucca Mountain and the surrounding area. In addition to this specific plan, the panel has made several general observations about previous geophysical efforts in and around Yucca Mountain and the management of those efforts. We will first discuss these general observations and related recommendations.

A. General Observations and Related Recommendations:

1. Coordination of Activities:

The major problem seen by the Panel during this peer review was the general lack of coordination in utilizing seismic methods to characterize the Yucca Mountain area. A specific example of this problem is seen in the use of the Vertical Seismic Profiling (VSP) method at the site. Because the USGS apparently does not have an in-house VSP expert, outside researchers from the Lawrence Berkeley Lab and Colorado School of Mines (and possibly other institutions) propose and carry out projects in this area. Although these researchers are capable, their projects are not integrated with the seismic reflection, refraction, or borehole logging data to the extent that they should be. The integration of seismic reflection, seismic refraction, VSP, and borehole logging data is critical to the success of any program at Yucca Mountain. In order to insure that these data are fully integrated and all related data acquisition, processing, and interpretation are focussed on specific objectives, it is imperative that the overall seismic program be organized and managed by an individual. The panel believes that the technical efforts as they are now organized are too disjointed. The success of the program in terms of the needs of the DOE (i.e. - in terms of characterizing the structural setting at the Yucca Mountain Repository Site) can be best met by placing the responsibility with an identified individual. Because the seismic reflection method is expected to provide the best resolved structural image at Yucca Mountain, and therefore is arguably the most critical technique, the Panel suggests that a reflection seismologist take on the overall technical responsibility for the application of all seismic methods at Yucca Mountain. This individual should be given adequate resources and authority to carry out a successful program. All proposed seismic reflection, refraction, VSP, and borehole acoustic logging programs should be organized and integrated through this person.

2. Integration of Results:

As stated in the previous paragraph, it is critical in any characterization project to integrate all data in order to obtain the best possible solution. In terms of the Yucca Mountain Repository Site Characterization, the issue of data integration and interpretation is even more critical. All geophysical interpretation is subject to some uncertainty and non-uniqueness. This uncertainty is reduced by integrating different sets of measurements with different techniques. Because these techniques (such as seismic reflection, VSP, seismic refraction, gravity, etc) have different ranges of uncertainty, the combination of techniques can allow the optimum solution to be reached. The reduction of uncertainty must be a top objective of using such data for the characterization of a licensed repository. The combination of results at the AV-1 Line site in the Amargosa Desert represents a good effort at such integration. The integration at the Yucca Mountain site, however, must be even better, and must include all borehole as well as surface data sets.

3. Program Objectives:

The panel spent a major part of the presentations and discussions on the issue of defining objectives for the use of seismic methods at Yucca Mountain. The panel believes that a successful application of seismic methods to the structural imaging at Yucca Mountain can only be obtained by following a specific set of objectives and tailoring any program to those objectives. It is the experience of the panel members that data acquisition without very specific objectives in terms of target depths and expected imaging problems will usually meet with failure. The failure of previous seismic reflection efforts at Yucca Mountain can be traced to a combination of difficult surface topography, deep water table, scatterers in the volcanic section, broadly defined objectives, and a lack of well control information. The panel members believe that better reflection seismic data can be obtained by carefully testing acquisition parameters, eliminating or minimizing difficult line geometry and surface effects, the full integration of borehole seismic data with the surface seismic data, and by focussing the efforts on a set of specific objectives. The specific objectives of the specific seismic program were described in a previous section. The panel feels strongly that the proposed program, as well as all future programs, be focussed on clearly defined, specific objectives which meet the needs of the DOE. It is not enough that the objectives meet the broad DOE needs, such as "support licensing efforts". The objectives must be specific, such as "provide a structural image of the Paleozoic-Tertiary boundary in order to identify faults which cut that boundary and penetrate to seismogenic depths and could be sources of future seismic activity at the site".

B. Specific Recommendations - Proposed Program

A proposed seismic reflection profile across Yucca Mountain was presented to the Panel by Dr. Tom Brocher. The panel has several recommendations concerning the acquisition of that data, as well as a number of related recommendations. All of these recommendations will be described in detail in this section. These recommendations are prefaced by several key comments: 1) the panel believes that the seismic reflection method can provide useful information concerning the structural setting at Yucca Mountain, specifically in the depth ranges of the Paleozoic-Tertiary contact; 2) the panel believes that it is critical that the reflection data be tied to the subsurface geology at a well point which penetrates the Tertiary section in an area of expected good quality seismic data; 3) the panel believes that shear wave information may provide an additional avenue for obtaining useful structural information at Yucca Mountain, and as such suggests that a shear wave source test be carried out prior to acquiring the seismic profile. Each of these points will be touched on in more detail in the following discussion of specific recommendations.

1. Overview of Specific Seismic Program

The Panel recommends that a four (4) part program be undertaken to test the utility of seismic reflection data for characterizing the structural setting of the Yucca Mountain area. The Panel feels strongly that all four (4) parts of the program must be completed in order to provide the highest probability of success. The four parts of the program are:

a) drill or extend a deep hole in Crater Flat to provide depth control and allow for the identification of seismic reflectors in an area where good quality seismic reflection data is expected. Suggest possibility of deepening VH1 well.

b) undertake a full seismic noise test in Crater Flat, test 2D receiver arrays as well as linear arrays - perform an expanding spread test using both P and S wave sources to obtain a quick look at the reflection quality in the area and see if shear wave reflections might provide structural information in areas of unsaturated rock.

c) acquire a P wave seismic reflection profile across Crater Flat through the deep control well, across Yucca Mountain, and continuing into Jackass Flats or beyond.

d) Acquire a standard VSP in the deep control well to tie the seismic data to measured depth and to identify reflectors correctly (possible 3 component survey if shear data is useful).

These four steps will provide a complete test of the utility of seismic data at Yucca Mountain, will provide a control point for tying the data to depth and allowing an accurate interpretation of the data, will test the applicability of shear wave data especially in unsaturated zones where these data may have advantages. After the completion of these activities, a major decision point is reached. At that point additional data may be acquired (including the possibility of high frequency 3-D seismic reflection data), shear wave data may be warranted, or seismic reflection data acquisition may be abandoned at Yucca Mountain.

In the following sections each of the four parts of the program will be described in more detail with specific suggestions for optimizing the acquisition efforts. The role of the seismic refraction method in characterizing Yucca Mountain will also be discussed.

2. Deep Control Borehole

The objectives of acquiring seismic reflection data in and around Yucca Mountain, as stated in a previous section, are to image the structure at the Paleozoic-Tertiary (Pz-T) contact and throughout the Cenozoic section. The reasons for these specific objectives are to see if the Pz-T contact is a detachment surface or if the normal faults in the area penetrate that contact and continue to seismogenic depths. In addition, by providing data on the Tertiary and Quaternary structure, more accurate dating of structural deformation can be obtained. In order to address these objectives, the seismic data which is acquired must be tied to a deep borehole for depth control and the accurate identification of specific reflectors. The only boreholes which penetrated the Pz-T contact are up on Yucca Mountain itself (U25P1). These boreholes will also be used to tie the seismic data, but the acquisition of good quality data at Yucca Mountain itself is by no means assured. This points out the need for a deep control borehole in an area of expected good quality seismic data. The Panel suggests that the best location for such a borehole is in Crater Flat. We further suggest that the deepening the existing VH1 well in Crater Flat be considered because of its location and to reduce costs.

3. Noise Tests and Expanding Spreads

Prior to acquiring any seismic reflection data at Yucca Mountain, a thorough testing program must be undertaken. The seismic reflection profiling effort proposed by the USGS adequately addresses this need, and the testing effort put forth by Dr. Brocher in the Amargosa Desert (Line AV-1) illustrates their resolve on this issue. The Panel suggests that in addition to the test parameters which were used in the Amargosa Desert, the following tests be included:

a) test the use of 2-dimensional receiver arrays (on the order of 200' across) to help attenuate energy propagating at oblique angles to the line (due to topography)

b) Lower the vibrator sweep frequency at the low end to add an octave to the sweep band (at the AV-1 line a sweep of 10-44 Hz was used, try to lower this to 5-44 Hz)

c) add more sweeps per vibrator point to increase the total source energy (at line AV-1, 12 sweeps per vibrator point were vertically stacked, test increasing this to 24 sweeps at Yucca Mountain)

d) also test the use of dynamite sources (for items 'c' and 'd': the Panel expects that higher source power will be needed to propagate through the thick unsaturated Tertiary section at Crater Flat and Yucca Mountain than was needed at the Amargosa Desert area to the south)

e) perform noise study using shear wave sources

f) perform and expanding spread profile using both compressional and shear wave sources

All testing should be done near the site of the control well (borehole VH-1, for example). Items 'e' and 'f' above concern the use of shear wave sources during the test phase of the proposed program. Because of the thick unsaturated zone which is present at Yucca Mountain, it is possible that shear waves could propagate with less attenuation than compressional waves and therefore provide some structural information. The basis of suggesting this possibility is two fold. First, the analysis of borehole logging information presented by Dr. Phil Nelson of the USGS indicates that the unsaturated zone is actually partially saturated. In such a setting, capillary forces would result in the fluids occupying the thin, grain contact pore spaces. The result would be grain contact continuity and hence lithologic rigidity capable of transmitting shear wave energy. The large volume of unsaturated pore space, however, may effectively attenuate much of the compressional energy propagating through the unit. The second reason for investigating the use of shear wave sources is from seismic data sets acquired in the vicinity of Yucca Mountain. Hasbrouck (1986, in "Shear Wave Exploration", SEG Monograph) collected shallow shear wave seismic data using a hammer source at Yucca Mountain. His data suggest the presence of shear wave reflection events. A multi-component VSP experiment at the Nevada Test Site (presented by Dr. Ernie Majer of the Lawrence Berkeley Lab) also suggests the presence of shear wave reflectors in the Tertiary section. These rationale are tenuous; however, the collection of an expanding spread profile using a shear wave source (after initial noise tests with a shear source as well) will only add a small amount to the overall cost of the program and will provide strong evidence about the utility of shear wave data at Yucca Mountain.

4. Seismic Reflection Profile

The Panel believes that the acquisition of a seismic reflection profile over Yucca Mountain will provide useful data for addressing the objectives defined in a previous section. The Panel expects that good quality data will be obtained in Crater Flats. The acquisition of useful seismic reflection data over Yucca Mountain, however, will be very difficult. The Panel makes the following suggestions to help optimize the results in this area:

a) the proposed line location must be straightened out to avoid smearing the common reflection points over an unacceptably large area under Yucca Mountain (Figure 1), and should also be tied into the UE25P#1 borehole for additional control.

b) undershoot Yucca Mountain by leaving receiver spreads on one side of the mountain and shooting sources on the other side (and vice-versa) ; decrease the shot point interval during this exercise to build up the fold under Yucca Mountain.

c) place receiver groups over the top of Yucca Mountain and acquire as many source points as possible.

The use of two dimensional arrays, as suggested in the testing section, may help reduce the topographically related noise which is expected for source points on Yucca Mountain. The Panel also recommends the use of computer modeling to aid in the design of the seismic acquisition effort, particularly for the undershooting of Yucca Mountain.

5. Vertical Seismic Profiling (VSP)

The acquisition of a conventional VSP in the deep control borehole is essential for the accurate interpretation of the seismic reflection profile. A VSP in this borehole will provide velocity information for the entire section (including the unsaturated sections which cannot be logged), provide accurate identification of reflections in the seismic profile, and provide a detailed structural image of the area around the control borehole. This last point should not be overlooked since it is expected that blocks of Paleozoic material from debris slides off Bare Mountain to the west (megabreccias) may be present. It is important, therefore, to use VSP data to ensure that the borehole has indeed penetrated the Paleozoic-Tertiary contact, rather than one of these breccia blocks.

The Panel stresses the following points in regard to the acquisition of this VSP:

a) the VSP design and acquisition must be coordinated with the reflection work to ensure success

b) the deep control well must have a good, complete cement job behind casing in order to get adequate horizontal geophone coupling for offset VSP and shear wave VSP acquisition

c) the issue of tool coupling in dry boreholes must be adequately addressed when designing the experiment and selecting equipment (most VSP and checkshot data at Yucca Mountain is not useable above the water table because of this problem)

Finally, the Panel recommends a standard offset VSP (compressional wave source with three component, directional ,clamped geophone) be acquired. However, if the shear wave testing results are positive, a 9 component VSP may be justified (three component source with three component receivers). Such an experiment requires very careful planning to be successful.

6. Role of the Seismic Refraction Method

The focus of this Peer Review Report is on the utilization of the seismic reflection method to obtain high resolution structural information at Yucca Mountain. The panel also discussed the role that seismic refraction methods could play in supplementing this objective, and providing independent data on the structural geology at the site. Although some disagreement exists within the committee concerning the applicability of the refraction method for providing information on the shallow Tertiary structure, there is a clear consensus that interpretation of refraction data at Yucca Mountain is very difficult for three reasons: 1) the shallow Tertiary section contains alternating high and low velocity zones, 2) the sub-Tertiary "basement" is composed of highly variable lithologies with highly variable velocities, and 3) the steep, narrow basins in the Yucca Mountain area present a difficult geometry for acquiring adequate data. Any refraction work which is undertaken for shallow objectives, such as the structure within the Tertiary section or at the Paleozoic-Tertiary boundary, must address these issues.

In light of the fact that the previously acquired Yucca Mountain reconnaissance refraction survey was conducted using large station spacing and few shots, the panel suggests that if explosive sources are used for any portion of the proposed reflection profile across Crater Flat and Yucca Mountain, consideration be given to recording wide angle/refraction data simultaneously. Such data would provide additional velocity information as well as potentially useful refraction information about the deeper section at Yucca Mountain. The use of close station spacing, numerous shots, and appropriate analysis techniques may provide useful results.

CHAIRMAN'S ACKNOWLEDGMENTS

The Peer Review which was held at the Yucca Mountain Project Office in Las Vegas during the week of September 10-13, 1990 owes its success to the efforts of a number of people. The panel members took time from their busy schedules to apply their knowledge and expertise as an aid to a problem of national importance. They deserve additional recognition for the open and constructive dialogue and exchange which characterized this review. The scientists from the USGS also are acknowledged for their presentations and efforts during the review. Specifically, Ken Fox, Tom Brocher, Phil Nelson, and Walter Mooney made presentations to the panel. The panel greatly benefitted from the field trip which was led by Ken Fox. Ernie Majer (Lawrence Berkeley Lab) also made a presentation to the panel. Finally, thanks are also due to Forrest Peters and Ernie Hardin of SAIC and Chris Fridrich and Jerry Boak of DOE for their efforts during the course of the review.

APPENDICES

APPENDIX A

PEER REVIEW PLAN

PEER REVIEW PLAN FOR PEER REVIEW OF SEISMIC METHODS AT YUCCA MOUNTAIN

Purpose

The purpose of the peer review shall be to review a project proposal for, and develop recommendations for strategy to be used for structural profiling across the Yucca Mountain site and adjacent areas, for intermediate depth targets in the vicinity of the Paleozoic contact. The recommendations shall describe the applicable seismic methods and acquisition parameters to be used, and processing methods to be applied. The review shall consider the applicability of available data for designing a seismic program, the use of existing boreholes where practicable, and the recommended orientation and location of geophysical traverses across the site area. If multiple, successively applied methods are recommended, the product shall describe how the recommended program should adapt as new data are acquired.

Results from this peer review will assist the DOE in deciding what program will be used in the characterization of the Yucca Mountain area.

The schedule for this peer review is presented as Enclosure 1.

Quality Assurance

This peer review will be performed in accordance with existing project requirements for quality assurance and with the Yucca Mountain Project Office Quality Management Procedure (QMP)-03-01, "Peer Review".

Peer Review Chairperson and Technical Secretary

The DOE Regulatory and Site Evaluation Division (RSED) Director, Maxwell Blanchard, has appointed Dr. Daniel R. Burns of NER Geoscience, as Chairperson. The Chairperson is responsible for conducting the peer review.
Jeremy M. Boak has been appointed as Technical Secretary. The technical Secretary facilitates the peer review process and assures that a peer review record is compiled.

Peer Reviewers

The peer reviewers were selected according to QMP-03-01, and are listed on Enclosure 2.

Peer Review Package

The peer reviewers will be provided with a package of representative publications that describe the existing geophysical information which has already been acquired in the vicinity of Yucca Mountain. The peer review package is to be read before the peer review meeting.

Peer Review Meeting

The peer review team will meet in Las Vegas from September 11-14, 1990. A one-day field trip to Yucca Mountain will precede the peer review meeting on

September 10, 1990, and will be attended by a subgroup of the peer review team.

The peer review Chairperson will prepare an agenda for this meeting. It will include an introduction and overview by the RSED Director, a background presentation on the Yucca Mountain geology, hydrology, and tectonic framework (presented by the Unites States Geological Survey), and technical presentation by the Principal Investigators on the proposed geophysical program.

Peer Review Record Memoranda

The peer review team will prepare a summary report including the review team's consensus, minority positions, conclusions and recommendations. This summary report (the Peer Review Record Memoranda) will address the questions in Enclosure 3. The summary report will be reviewed and will be signed by all of the peer review members, and will be submitted to the DOE by October 15, 1990.

Records

The Technical Secretary will assure that a complete record is maintained of the peer review team's actions. At the conclusion of the review, he will, with the assistance of the Chairperson, review all records for completeness, and assure that they are placed in the Project records system, in accordance with QMP-17-01.

SEISMIC METHODS PEER REVIEW PANEL

	Panel Member	Expertise
1.	Dr. Daniel R. Burns, Chairman NER Geoscience One Kendall Square, Suite 2200 Cambridge, MA 02139 (617)-621-7091	seismic wave propagation, rock properties, borehole acoustics
2.	Dr. Steven Danbom MS 6451 RW Conoco P.O. Box 1267 Ponca City, OK 74603 (405)-767-3158	seismic acquisition, shear wave exploration, environmental geoscience
3.	Dr. Clint Frasier Chevron Oil Field Research Company P.O. Box 446 1300 Beach Blvd. La Habra, CA 90633-0446 (213)-694-7214	seismic data acquisition and interpretation
4.	Professor George Thompson Geophysics Department Stanford University Palo Alto, CA (415)-723-3714	seismic data analysis, Basin and Range tectonics
5.	Dr. Roger Turpening Earth Resources Laboratory Massachusetts Institute of Technology 42 Carleton Street Cambridge, MA 02142 (617)-253-7850	borehole geophysics, data acquisition
6.	Dr. Terry Young Mobil Research P.O. Box 819047 Dallas, TX 75381 (214)-851-8237	seismic data acquisition and processing

1. What is the likelihood that seismic reflection profiling can image the structural setting of the Paleozoic/Tertiary contact?

2. What is the likelihood that seismic reflection profiling can image the fault pattern at, above, and below the Paleozoic/Tertiary contact?

3. Can seismic refraction provide adequate resolution to locate the Paleozoic/Tertiary contact?

4. Can seismic refraction provide adequate resolution to provide information on the fault patterns at and near the Paleozoic/Tertiary contact?

5. What data acquisition methods should be used to optimize the seismic reflection data at Yucca Mountain in the depth range of the Paleozoic/Tertiary contact ?

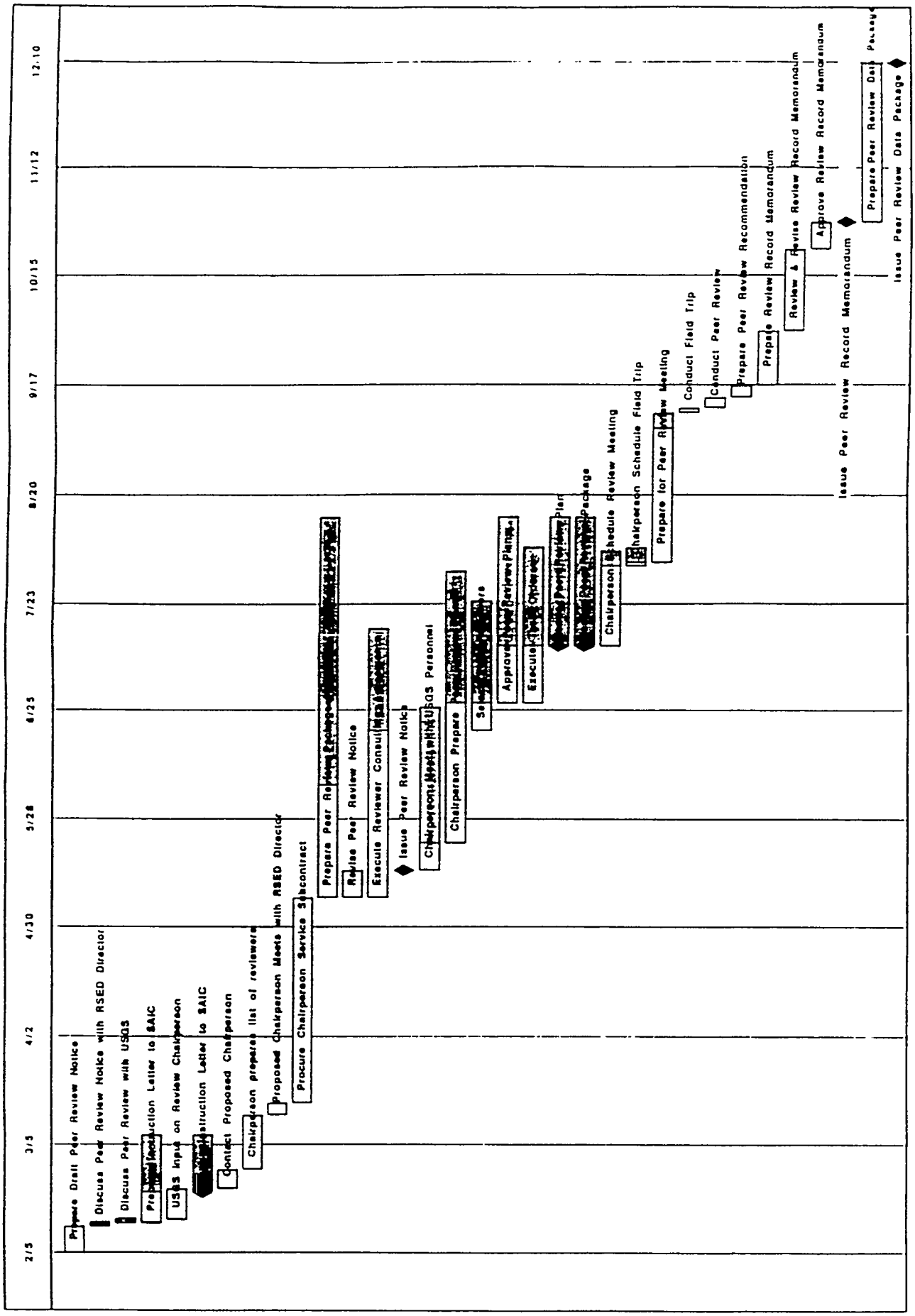
6. What data acquisition methods should be used to optimize the seismic refraction data at Yucca Mountain in the depth range of the Paleozoic/Tertiary contact ?

7. What data processing methods should be used to optimize the structural imaging in the depth range of the Paleozoic/Tertiary contact using seismic reflection data?

8. What role should borehole seismic methods play in optimizing the structural imaging in the depth range of the Paleozoic/Tertiary contact using seismic reflection data?

9. If the seismic methods can provide information on the structural geology of Yucca Mountain, how should the exploration be phased to maximize results and utilize all prior information?

ENCLOSURE 1


2/5
3/5
4/2
4/30
5/28
6/25
7/23
8/20
9/17
10/15
11/12
12.10
Prepare Draft Peer Review Notice
Discuss Peer Review Notice with RSED Director
Discuss Peer Review with USGS
USGS Input on Review Chairperson
Contact Proposed Chairperson
Chairperson prepares list of reviewers
Proposed Chairperson Meets with RSED Director
Procure Chairperson Service Subcontract
Prepare Peer Review Notice
Execute Reviewer Consultation
Issue Peer Review Notice
Chairperson Meets with USGS Personnel
Chairperson Prepare
Approve Peer Review Plan
Execute Peer Review Plan
Chairperson Schedule Review Meeting
Chairperson Schedule Field Trip
Prepare for Peer Review Meeting
Conduct Field Trip
Conduct Peer Review
Prepare Peer Review Recommendation
Prepare Review Record Memorandum
Review & Revise Review Record Memorandum
Approve Review Record Memorandum
Issue Peer Review Record Memorandum
Prepare Peer Review Data Package
Issue Peer Review Data Package

APPENDIX B

PEER REVIEW PACKAGE CONTENTS LIST

I N T E R O F F I C E M E M O R A N D U M

Date: 18-Aug-1990 10:40am PDT
From: Forrest Peters
PETERSF
Dept: Technical Support
Tel No: 794-7753

TO: See Below

Subject: Seismic Peer Review Package

The following documents are being sent to you in preparation for the upcoming Seismic Peer Review to be held September 10 through 14, 1990.

1) Peer Review Plan for the Peer Review of Seismic Methods at Yucca Mountain, July 31, 1990. (Draft)

2) Statement of Objectives and Proposal for a Geophysical Profile across the Yucca Mountain Site, USGS, July 13, 1990.

3) Feasibility Study of the Seismic Reflection Method in the Amargosa Desert, Nye County, Nevada, USGS OFR 89-133.

4) Waste Management Project Office Quality Management Procedure QMP-03-01, Peer Reviews, Revision 1, ICN Numbers 1 and 2.

5) Snyder, D.B., and Carr, W.J., 1984. Interpretation of Gravity Data in a Complex Volcano-Tectonic Setting, Southwestern Nevada, JGR v. 89-B12.

6) Serpa, L., et al. 1988. Structure of the Death Valley pull-apart basin and vicinity from COCORP profiles in the southern Great Basin. GSA Bull. v.100.

7) de Voogd, B., et al. 1986. Death Valley bright spot: A midcrustal magma body in the southern Great Basin, California?, Geology v.14.

8) Carr, W.J., and Parrish, L.D., 1985. Geology of drill hole VH-2, and structure of Crater Flat, Southwestern Nevada. USGS-OFR-85-475.

9) Barry, C.T., 1980. A study of the vertical vibrator source for seismic profiling in the Yucca Mountain area of the Nevada Test Site. MS Thesis, CSM ER-2429.

10) Ackermann, H.D., et al. 1988. Preliminary interpretation of seismic-refraction and gravity studies west of Yucca Mountain, Nevada and California. Chapter 3 in USGS-Bulletin 1790.

11) Carr, W.J., 1988. Volcano-tectonic setting of Yucca Mountain and Crater Flat, southwestern Nevada. Chapter 4 in USGS-Bulletin 1790.

12) Hamilton, W., 1988. Detachment faulting in the Death Valley region, California and Nevada. Chapter 5 in USGS-Bulletin 1790.

13) Carr, M.D., et al, 1986. Geology of drill hole UE25p#1: A test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada. USGS_OFR-86-175.

14)de Voogd, B., et al, 1988. Crustal extension and magmatic processes: COCORP profiles from Death Valley and the Rio Grande rift. GSA Bull. v. 100.

15) McGovern, T.F., 1983. An evaluation of seismic reflection studies in the Yucca Mountain area, Nevada Test Site. USGS-OFR-83-912.

16) Hoffman, L.R., and Mooney, W.D., 1984. A seismic study of Yucca Mountain and Vicinity, southern Nevada; Data report and preliminary results. USGS-OFR-83-588.

17) McArthur, R.D., and Burkhard, N.R., 1986. Geological and geophysical Investigations of Mid-Valley. LLNL-UCID-20740.

18) Oliver, H.W., et al, editors, 1990. Status of data, major results, and plans for geophysical activities, Yucca Mountain Project. YMP/90-38.

The detailed boring logs and some other relatively unimportant pages have been removed from several of these publications. This information would be available during the review, if needed.

We look forward to your participation in this peer review.

Distribution:

TO:	Steven Danbom (Conoco)	(PAPER MAIL)
TO:	Clint Frasier (Chevron)	(PAPER MAIL)
TO:	George Thompson (Stanford)	(PAPER MAIL)
TO:	Roger Turpening (MIT)	(PAPER MAIL)
TO:	Terry Young (Mobil)	(PAPER MAIL)
TO:	Chris Fridrich	(FRIDRICHC)
CC:	Forrest Peters	(PETERSF)
CC:	Jeremy Boak	(BOAKJ)

cc: Terry Grant
cc: Daniel Burns

APPENDIX C

FINAL MEETING AGENDA

PEER REVIEW PANEL
ON SEISMIC REFLECTION AND REFRACTION METHODS

FINAL MEETING AGENDA
SEPTEMBER 9 - 14, 1990
LAS VEGAS, NEVADA

Monday September 10, 1990

7am - 7pm	field trip to Crater Flat and Yucca Mountain (meet at front of 101 Convention Center Drive at **7am**)

Tuesday September 11, 1990 (at DOE Yucca Mountain Project Office)

1:00 PM	D. Burns
1:30 PM	K. Fox, Geology and Tectonics overview, USGS
3:30 PM	Break
4:00 PM	T. Brocher, USGS, Review of Proposal (fit in to tectonics question)
5:30 PM	Adjourn

Wednesday, September 12, 1990 (at DOE Yucca Mountain Project Office)

8:00 AM	D. Burns
8:15 AM	P. Nelson, USGS (Logging, sonic and density)
9:15 AM	E. Majer, LBL (Check shot data, VSP methodand data)
10:15 AM	Break
10:45 AM	W. Mooney, USGS (Refraction data results)
12:00 Noon - 1:30 PM	Lunch
1:30 PM	W. Mooney, USGS (Refraction data plans)
2:15 PM	T. Brocher, USGS (reflection results and data sets)
3:15 PM	Break

3:45 PM T. Brocher, USGS (Proposed reflection acquisition and processing)

5:00 PM Panel Conference

5:30 PM Adjourn

Thursday September 13, 1990 (at DOE Yucca Mountain Project Office)

8:00 AM Panel Conference

12:00 Noon Lunch

1:00 PM Panel Conference

4:00 PM Presentation of Panel Recommendations (videotape)

5:30 PM Adjourn

APPENDIX D

T. YOUNG LETTER

M bil Research and Development Corporation

RESEARCH DEPARTMENT
DALLAS RESEARCH LABORATORY
P O. BOX 819047
DALLAS, TEXAS 75381 9047

13777 MIDWAY ROAD
DALLAS, TEXAS 75244-43'2

M P RAMAGE
MANAGER

September 10, 1990

Dr. Daniel R. Burns
% Forrest Peters
Science Applications International Corporation
101 Convention Center Drive, Suite 407
Las Vegas, Nevada 89109

Dear Dan:

I am sorry to have to confirm that I will be unable to participate in this week's activities of the DOE Seismic Reflection and Refraction Peer Review Panel. At the time Mobil agreed to my serving on the Panel, neither my management nor I anticipated that I would be assigned new internal responsibilities that would prevent me from participating in the Panel's scheduled program.

I apologize for the disruption we have caused in the Peer Review program. I am personally disappointed to be unable to follow through on my professional commitment to you.

Best regards,

Terry Young

T. K. Young
Planning Associate II

TKY/it

cc: M. G. Bloomquist
M. P. Ramage
D. M. Summers
Records Center

APPENDIX E

FINAL PEER REVIEW PANEL MEMBER LIST

SEISMIC METHODS PEER REVIEW PANEL

FINAL LIST

	Panel Member	Expertise
1.	Dr. Daniel R. Burns, Chairman NER Geoscience One Kendall Square, Suite 2200 Cambridge, MA 02139 (617)-621-7091	seismic wave propagation, rock properties, borehole acoustics
2.	Dr. Steven Danbom MS 6451 RW Conoco P.O. Box 1267 Ponca City, OK 74603 (405)-767-3158	seismic data acquisition and processing; shear wave exploration; environmental geoscience
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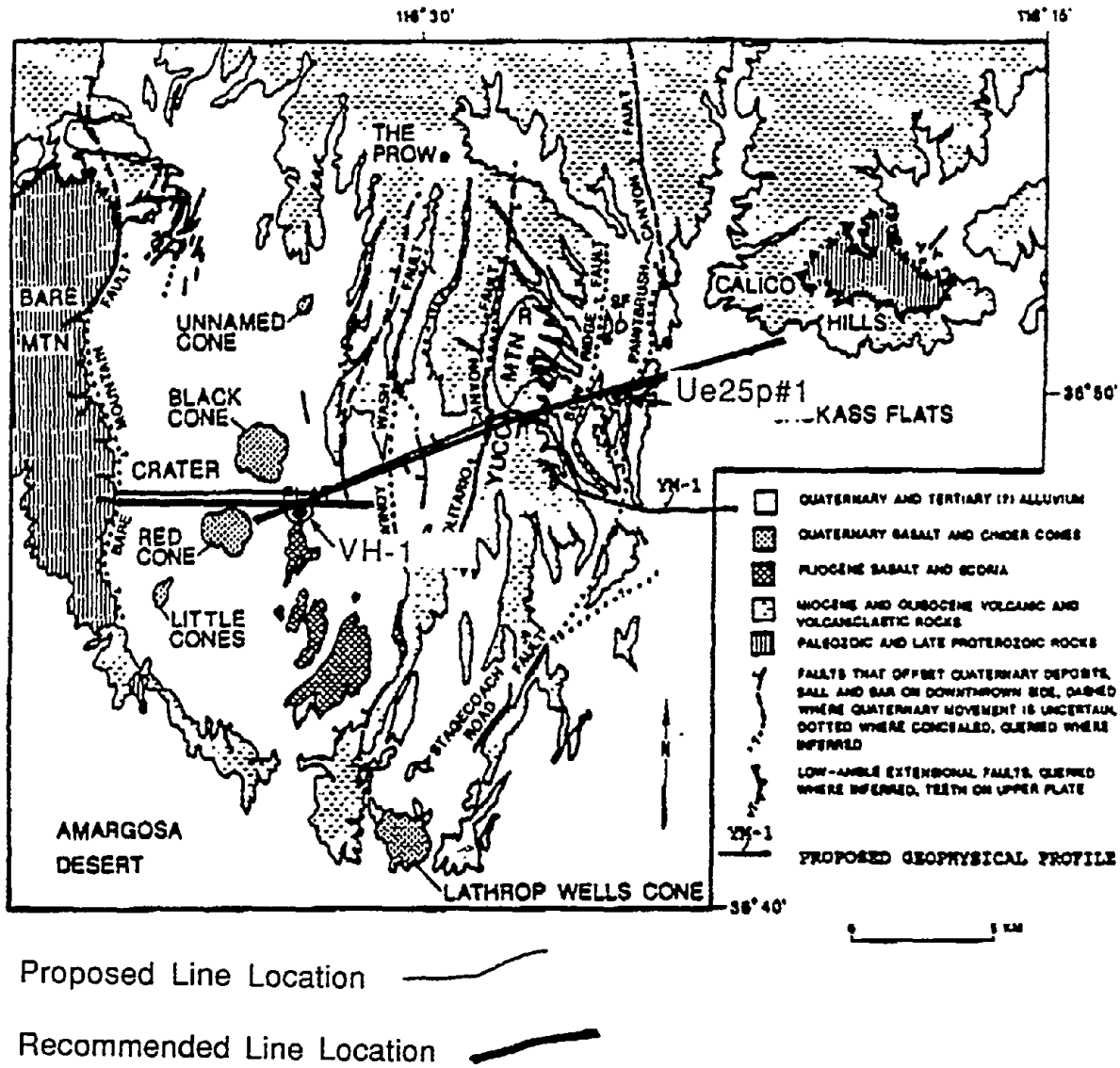

Figure 1: Panel's recommended location for the proposed seismic reflection line.

(from Brocher, T., Statement of objectives and proposal for a geophysical profile across the Yucca Mountain site (NN1-1990-3490); geologic map modified from Swadley, Hoover, and Rosholt, 1984, USGS Open File Report 84-788, 42 p.)